



THE ROLE OF CURCUMIN IN CANCER

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ABSTRACT

Cancer is a life-threatening disease and one of the leading causes of death worldwide. Curcumin, a compound in turmeric, shows potential in cancer treatment but is hindered by low bioavailability and solubility. Curcumin is a polyphenol extracted from the rhizomes of the turmeric plant, *Curcuma longa*, which has anti-inflammatory and anticancer properties. Curcumin, an orange crystalline powder derived from the herbs of *Curcuma longa* L. (Zingiberaceae), is a natural hydrophobic polyphenol obtained from the powdered rhizomes of *Curcuma longa* L. *Curcuma Longa* (Turmeric) is an herb. Several studies have demonstrated that curcumin exhibits a wide spectrum of biological and pharmacological properties, including antiproliferative, antioxidant, chemopreventive, antibacterial, anti-inflammatory, and anti-carcinogenic activities. Chronic inflammation is associated with the development of cancer. Nanocurcumin shows promise as an innovative approach in cancer therapy, potentially offering improved efficacy and reduced side effects compared to traditional treatments. Early clinical trials indicate its potential to enhance the quality of life for cancer patients by mitigating treatment-related toxicities and improving therapeutic outcomes.

KEYWORDS: Curcumin, Nanoparticles, Drug Delivery System, Antimicrobial Activity, Curcumin, Curcumin Nanoparticles

INTRODUCTION

Traditional cancer treatments, such as chemotherapy and radiotherapy, frequently result in harmful side effects and the development of drug resistance (1,2)

Cancer immunotherapy has brought significant improvements for patients in terms of survival and quality of life (3)

Curcumin, a biologically active chemical extracted from the rhizome of *Curcuma longa* (turmeric), has attracted considerable interest due to its possible anti-cancer capabilities (4)

Multiple preclinical studies have shown that curcumin can influence various cellular pathways in cancer advancement, such as cell proliferation, apoptosis, angiogenesis, and metastasis (5,6)

The practical application of curcumin in medical settings has been impeded by its limited capacity to dissolve in water, its low rate of absorption into the body, and its quick breakdown by metabolic processes (7)

Nanotechnology has arisen as a viable approach to address the constraints of traditional medication delivery techniques (8).

Peptides and nanoparticles work synergistically in cancer

treatment. Nanoparticles functionalized with peptides can target tumour cells better (9)

Nanocurcumin, nano formulations of curcumin, have been created to improve its solubility, stability, and bioavailability (10)

The nano formulations consist of different platforms, including polymeric nanoparticles, liposomes, micelles, and nano emulsions (11)

The combination of nanotechnology and curcumin has created new possibilities for cancer treatment. (13)

Due to their biochemical structures, natural compounds can affect numerous cellular targets, such as genes and proteins (14)

Herbal preparations and their related natural products offer a pivotal role in cancer chemotherapy and chemoprevention. (15)

Researchers are investigating herbal medicines, natural medicine, and nutrition to address the typical main difficulties in traditional cancer therapy (16)

Curcumin is the primary polyphenol isolated from the rhizomes of *Curcuma longa* L. (family Leguminosae), which has a long-

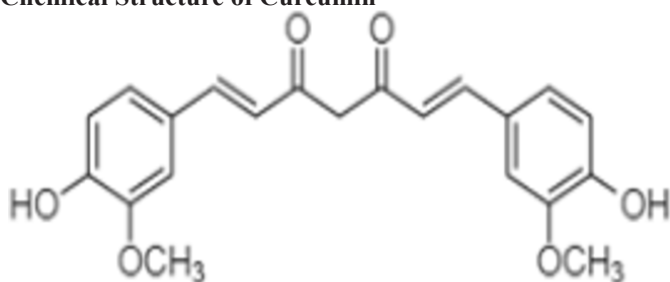
standing tradition of usage throughout East Asian nations as a curry powder (turmeric) (17)

Curcumin has a variety of therapeutic applications, exhibiting anti-inflammatory, antioxidant, antidiabetic, antibacterial, antifungal, antiproliferative, anticancer, and hepatoprotective effects (18)

Curcumin loaded in poly (lactic-co-glycolic acid) (PLGA) nanospheres was synthesized by using the solid/oil/water emulsion solvent evaporation technique. PLGA-loaded Nano curcu are one of the efficient tools which can be used in the cancer therapy [19].

Curcumin-loaded PLGA nanoparticles were found to be novel candidates in the treatment of ovarian cancer [20].

Chemical Structure of Curcumin



The most common strategy involves encapsulating curcumin into nanocarriers, such as nanoparticles or nano capsules. To protect curcumin and improve its delivery efficiency (21)

Anti-Cancer Activity of Curcumin

Like gemcitabine and cisplatin as chemotherapeutic medications, it inhibits the development of malignant cells with an IC₅₀ ranging from 5 to 30 μ M (22,23)

A clinical trial involving 15 people with colorectal cancer found that the cancer was unresponsive to curcumin at 3.6 g/day over four months (24)

According to this report, tumour biomarkers and tumorigenesis did not change. Generally, the experiments found that while curcumin has anti-tumour properties at a rate of 5–30 μ M for 1–2 days, owing to curcumin's better metabolic functions and its poor bioavailability, reaching these levels at the tumour location in human populations has not been possible (25)

Curcumin nano formulations have been produced and adapted by different generic and pharmaceutical companies to improve solubility and dissolution rate.(26)

To mitigate this problem, cyclodextrin, an adjuvant, and some proprietary innovations were originally employed (27))

There have been several efforts to enhance the bioavailability of curcumin with the aim of increasing its effectiveness, but these approaches may not have the potential to deliver curcumin into tumours. (28)

Curcumin has been shown in several experiments to serve as an inhibiting factor, preventing cancer development in its early stages. It also acts as a suppressive factor, preventing the proliferation of malignant cells during the progression of carcinogenesis. Curcumin's antitumor pathways are extensive but diverse, involving various phases of the apoptosis processes and cellular growth. Because curcumin has a plethora of targets and functionalities on cellular growth regulatory pathways, it holds a lot of promise as a chemotherapeutic agent against human solid tumours (29,30)

Furthermore, curcumin's activity on a variety of transcription factors, oncogenes, and signalling proteins affects metastatic spread, tumorigenesis, and cancer development at various levels of carcinogenesis, beginning with early repercussions that cause DNA mutation (31,32)

Curcumin slows tumour development by blocking specific signalling pathways, including inhibiting transcription factors involved in tumorigenesis, viz., signal transducers, activating protein-1 (AP-1), and transcription (STAT) protein activators (33)

It causes apoptosis by prohibiting the misfolded N-CoR protein and disrupting of the ubiquitin–proteasome pathway. Protein kinases are another target of curcumin. Curcumin inhibited the mitogen-activated protein kinase function and epidermal growth-factor receptor activity in lung and pancreatic adenocarcinoma cells (34)

In another study, the antiproliferative effects of Gemini curcumin and free curcumin were investigated against ovarian cancer (OVCAR-3 cells). The results showed that compared with pure curcumin, Gemini surfactant nanoparticles increase the cellular uptake and effectively suppress the proliferation of OVCAR-3 cells via induction of apoptosis (35)

Additionally, Sobhkhizi et al. revealed that dendrosomal nanocurcumin could be used as an anti-tumor medicine in p53-mutant tumor malignancies (36).

Curcumin's capacity to induce apoptosis, disrupt cell cycle activity, and inhibit proliferation of cancer cells makes it a possible therapy for human breast (especially MCF-7, MDA-MB-231, MDA-MB-468, and SkBr-3 cells), lung, colorectal, prostate, carcinoma, melanoma, liver, myeloma, and pancreatic cancers (37,38)

Curcumin has been shown to inhibit cancer cell metastasis development. It prevents cancer cells from destroying healthy tissue by inhibiting the action of matrix metalloproteinases, which control the mechanism.(39)

Curcumin inhibits the expression of genes participating in tumor development, apoptosis, and proliferation, such as c-myc, cyclin D1, Bcl-xL, and Bcl-2. NF- κ B suppression is essential in proliferation and carcinogenesis. Curcumin inhibits the function of NF- κ B, which may enhance the expression of genes involved in invasion (for example, matrix metalloproteinases),

proliferation (for example, c-myc and cyclin D1), and antiapoptotic (40)

Turmeric is effective in treating various types of cancer

Curcumin, the principal curcuminoid of turmeric, has 14 molecules with cancer preventive potential and 12 with anti-tumour effect. Curcuma longa, also known as turmeric, is effective in the treatment of various types of cancer, including breast and ovarian cancer, which has risen 30 percent among women in the last decade, says a study. Turmeric has nearly 20 molecules with antibiotic properties, 14 molecules with cancer preventive potential, and 12 with antitumor effect, says the study conducted by BL Kapoor Memorial Hospital, New Delhi. (41)

Advanced nanomedicine to treat oral cancer has been developed. The effectiveness of the medicine — ‘BRECAN’, developed using nano curcumin — was documented during clinical trials, and has been published in the Journal of Oral and Maxillofacial Pathology, brought out by the Indian Association of Oral and Maxillofacial Pathology. Dr Vijay Kanuru, a bio-nano scientist with Oncocur, has developed an advanced cost-effective nanomedicine for the treatment of early-stage oral cancer and its prevention. The effectiveness of the medicine — ‘BRECAN’, developed using nano curcumin — was documented during clinical trials, and has been published in the Journal of Oral and Maxillofacial Pathology, brought out by the Indian Association of Oral and Maxillofacial Pathology.

Turmeric may help in treating blood cancer, say IIT Madras researchers

The results of this work were recently published in the reputed peer-reviewed journal Pharmacological Reports. Indian Institute of Technology Madras (IIT-M) researchers have shown that curcumin -- the active principle from turmeric -- may enhance cancer cell death. The study showed that curcumin significantly increased the sensitivity of leukemia cells to a protein that causes death of cancer cells. The research however, showed these results in situ (in a test tube), and the outcome may vary in the human body. This doubt arises because curcumin is known to be poorly absorbed into the blood from the gut, and its bioavailability for therapeutic purposes is generally poor. There have been considerable efforts in developing therapeutic agents that trigger the death of cancer cells. One such agent that has been found promising is a protein called ‘TNF-Related Apoptosis-Inducing Ligand’ (TRAIL). Its ability to selectively kill cancer cells by ‘apoptosis’ has resulted in several preclinical studies being carried out all over the world. Curcumin enhances the sensitivity of the cancer cells to the TRAIL, the statement said. In cancer treatment, it is important to induce the death of cancer cells preferentially without extensive damage to healthy cells in the body. ‘Apoptosis’, or programmed cell death, is generally preferred over the more aggressive and premature ‘necrosis’ for killing cancer cells because it releases fewer cellular components that trigger inflammation than the latter. The study was led by Rama Shanker Verma, Bhupat, and Jyoti Mehta School of Biosciences, Department of Biotechnology, IIT Madras. The results of this work were recently published in the reputed peer-reviewed journal Pharmacological

Reports. The paper was co-authored by Sridevi Surapally and Madhumathi Jayaprakasam. Curcumin is already known to be a potent anti-cancer agent because of its ability to inhibit carcinogenesis and induce apoptosis in various cancer cells. Its function as a sensitizer to TRAIL has been shown in cases of prostate cancer, breast cancer, colon cancer, and malignant glioma, the statement said.(42)

Compound in turmeric may treat colon cancer

An ingredient found in turmeric, which is present in spicy curry dishes, may play an important role in treating colon cancer, researchers, including one of Indian-origin, have found in a new study.

Turmeric and Cancer

Some studies suggest the curcumin in turmeric has a variety of health benefits, including fighting cancer cells. Some lab studies have found it might work against lung, breast, prostate, and colon cancers. Others suggest that curcumin might help chemotherapy work better.

A study on people with colorectal cancer found it may help slow the disease’s progression. Another study found that taking it daily may lower the chance of cancer in people who are at high risk of it.

But most evidence about turmeric and cancer comes from studies on animals or cells in the lab. With those studies, it’s not clear what these studies mean for people who have cancer or those who are trying to avoid getting it.(43)

Bio-drug derived from turmeric is being developed to treat cancer

CSIR-CCMB and CSIR-NCL in collaboration

CSIR-Centre for Cellular & Molecular Biology (CCMB) scientists, in collaboration with CSIR-National Chemical Laboratory (NCL) announced on Thursday that they have made progress towards developing a non-toxic bio-drug derived from turmeric through a ‘gene silencing approach’ to treat cancer. CSIR-Centre for Cellular & Molecular Biology (CCMB) scientists in collaboration with CSIR-National Chemical Laboratory (NCL) announced on Thursday that they have made progress towards developing a non-toxic bio-drug derived from turmeric through a ‘gene silencing approach’ to treat cancer. RNA interference (RNAi) is a gene silencing approach and a promising tool for targeted and focused therapy for chronic diseases like cancer. The lack of safe and effective delivery methods for RNAi molecules is one of the key challenges to using RNAi-based therapy in biological systems.

CONCLUSION

Cancer has a major impact on societies across the world. The main cancer treatment methods are surgery, chemotherapy, and radiotherapy. Although there have been notable improvements in cancer diagnosis and therapy, there is still an urgent need for the development of treatment methods that are both safe and effective. Traditional cancer treatments, such as chemotherapy and radiotherapy, frequently result in harmful side effects and the development of drug resistance. It acts on the regulation

of different aspects of tumour development and interconnects with major signalling pathways that are dysregulated in cancer, such as the phosphatidylinositol-3-kinase/protein kinase B pathway. In an attempt to find new treatment options for cancer, attention has shifted to natural compounds. Curcumin is a polyphenol isolated from the roots of turmeric that possesses many biological properties. It acts on the regulation of different aspects of tumour development and interconnects with major signalling pathways that are dysregulated in cancer, such as the phosphatidylinositol-3-kinase/protein kinase B pathway.

REFERENCES

1. Arruebo M, Vilaboa N, Sáez-Gutiérrez B, Lambea J, Tres A, Valladares M, et al. Assessment of the evolution of cancer treatment therapies. *Cancers*. 2011;3(3):3279–330. [DOI] [PMC free article] [PubMed] [Google Scholar]
2. Nussbaumer S, Bonnabry P, Veuthey J-L, Fleury-Souverain S. Analysis of anticancer drugs: a review. *Talanta*. 2011;85(5):2265–89. [DOI] [PubMed] [Google Scholar]
3. Esfahani K, et al. A review of cancer immunotherapy: from the past, to the present, to the future. *Curr Oncol*. 2020;27(s2):87–97. [DOI] [PMC free article] [PubMed] [Google Scholar]
4. Mei L, Zhang Z, Zhao L, Huang L, Yang X-L, Tang J, et al. Pharmaceutical nanotechnology for oral delivery of anti-cancer drugs. *Adv Drug Deliv Rev*. 2013;65(6):880–90. [DOI] [PubMed] [Google Scholar]
5. Wolf CPJG, Rachow T, Ernst T, Hochhaus A, Zomorodbakhsch B, Foller S, et al. Interactions in cancer treatment considering cancer therapy, concomitant medications, food, herbal medicine and other supplements. *J Cancer Res Clin Oncol*. 2021;148:1–13. [DOI] [PMC free article] [PubMed] [Google Scholar]
6. Khodavirdipour A, Zarean R, Safaralizadeh R. Evaluation of the anti-cancer effect of *Syzygium cumini* ethanolic extract on HT-29 colorectal cell line. *J Gastrointest Cancer*. 2021;52:575–81. [DOI] [PubMed] [Google Scholar]
7. Bachmeier BE, Killian PH, Melchart D. The role of curcumin in prevention and management of metastatic disease. *Int J Mol Sci*. 2018;19(6):1716. [DOI] [PMC free article] [PubMed] [Google Scholar]
8. Mansouri K, Rasoulpoor S, Daneshkhah A, Abolfathi S, Salari N, Mohammadi M, et al. Clinical effects of curcumin in enhancing cancer therapy: a systematic review. *BMC Cancer*. 2020;20:1–11. [DOI] [PMC free article] [PubMed] [Google Scholar]
9. Dai J, Ashrafizadeh M, Aref AR, Sethi G, Ertas YN. Peptide-functionalized, -assembled and -loaded nanoparticles in cancer therapy. *Drug Discov Today*. 2024;29(7):103981. 10.1016/j.drudis.2024.103981. [DOI] [PubMed] [Google Scholar]
10. Islam MR, Islam F, Nafady MH, Akter M, Mitra S, Das R, et al. Natural small molecules in breast cancer treatment: understandings from a therapeutic viewpoint. *Molecules*. 2022;27(7):2165. [DOI] [PMC free article] [PubMed] [Google Scholar]
11. Scazzocchio B, Minghetti L, D'Archivio M. Interaction between gut microbiota and curcumin: a new key of understanding for the health effects of curcumin. *Nutrients*. 2020;12(9):2499. [DOI] [PMC free article] [PubMed] [Google Scholar]
12. Sabet S, Rashidinejad A, Melton LD, McGillivray DJ. Recent advances to improve curcumin oral bioavailability. *Trends Food Sci Technol*. 2021;110:253–66. [Google Scholar]
13. Nair KL, Thulasidasan AK, Deepa G, Anto RJ, Kumar GS. Purely aqueous PLGA nanoparticulate formulations of curcumin exhibit enhanced anti-cancer activity with dependence on the combination of the carrier. *Int J Pharm*. 2012;425(1–2):44–52. [DOI] [PubMed] [Google Scholar]
14. Khalifa S.A., Elias N., Farag M.A., Chen L., Saeed A., Hegazy M.E.F., Moustafa M.S., Abd El-Wahed A., Al-Mousawi S.M., Musharraf S.G., et al. Marine natural products: A source of novel anticancer drugs. *Mar. Drugs*. 2019;17:491. doi: 10.3390/md17090491. [DOI] [PMC free article] [PubMed] [Google Scholar]
15. Sarker S.D., Nahar L., Miron A., Guo M. Chapter 2—Anticancer natural products. In: Sarker S.D., Nahar L., editors. *Medicinal Natural Products: A Disease-Focused Approach*. Volume 55. Academic Press; Cambridge, MA, USA: 2020. pp. 45–75. [DOI] [Google Scholar]
16. Wolf C.P., Rachow T., Ernst T., Hochhaus A., Zomorodbakhsch B., Foller S., Rengsberger M., Hartmann M., Hübner J. Interactions in cancer treatment considering cancer therapy, concomitant medications, food, herbal medicine and other supplements. *J. Cancer Res. Clin. Oncol*. 2022;148:461–473. doi: 10.1007/s00432-021-03625-3. [DOI] [PMC free article] [PubMed] [Google Scholar]
17. Ahmad A., Sakr W.A., Rahman K.M. Novel targets for detection of cancer and their modulation by chemopreventive natural compounds. *Front. Biosci*. 2012;4:410–425. doi: 10.2741/e388. [DOI] [PubMed] [Google Scholar]
18. Tagde P., Tagde P., Islam F., Tagde S., Shah M., Hussain Z.D., Rahman M.H., Najda A., Alanazi I.S., Germoush M.O., et al. The multifaceted role of curcumin in advanced nanocurcumin form in the treatment and management of chronic disorders. *Molecules*. 2021;26:7109. doi: 10.3390/molecules26237109. [DOI] [PMC free article] [PubMed] [Google Scholar]
19. Mukerjee A, Vishwantha K (2009) Formulation, characterization and evaluation of curcumin-loaded PLGA nanospheres for cancer therapy. *AntiCan Res* 29:3867–3876.
20. Patumraj S, Yoysungneon P. Curcumin as a therapeutic agent against cancer. *Asian Biomed*. 2007, 1, 239–252.
21. Recent Developments in Delivery, Bioavailability, Absorption and Metabolism of Curcumin: the Golden Pigment from Golden Spice, Sahdeo Prasad, PhD, Amit K. Tyagi, PhD, Bharat B. Aggarwal, PhD, 2014.
22. Hu S., Xu Y., Meng L., Huang L., Sun H. Curcumin inhibits proliferation and promotes apoptosis of breast cancer cells. *Exp. Ther. Med*. 2018;16:1266–1272. doi: 10.3892/etm.2018.6345. [DOI] [PMC free article] [PubMed] [Google Scholar]
23. Koroth J., Nirgude S., Tiwari S., Gopalakrishnan V., Mahadeva R., Kumar S., Karki S.S., Choudhary B. Investigation of anti-cancer and migrastatic properties of novel curcumin derivatives on breast and ovarian cancer cell lines. *BMC Complement. Altern. Med*. 2019;19:273. doi: 10.1186/s12906-019-2685-3. [DOI] [PMC free article] [PubMed] [Google Scholar]
24. Sharma R.A., Euden S.A., Platton S.L., Cooke D.N., Shafayat A., Hewitt H.R., Marczylo T.H., Morgan B., Hemingway D., Plummer S.M. Phase I clinical trial of oral curcumin: Biomarkers of systemic activity and compliance. *Clin. Cancer Res*. 2004;10:6847–6854. doi: 10.1158/1078-0432.CCR-04-0744. [DOI] [PubMed] [Google Scholar]
25. Dei Cas M., Ghidoni R. Dietary curcumin: Correlation between bioavailability and health potential. *Nutrients*. 2019;11:2147. doi: 10.3390/nu11092147. [DOI] [PMC free article] [PubMed] [Google Scholar]
26. Desai K. Curcumin Cyclodextrin Combination for Preventing or Treating Various Diseases. No. US20100179103A1. U.S. Patent. 2010 July 15;
27. Jäger R., Lowery R.P., Calvanese A.V., Joy J.M., Purpura M., Wilson J.M. Comparative absorption of curcumin formulations. *Nutr. J*. 2014;13:11. doi: 10.1186/1475-2891-13-11. [DOI] [PMC free article] [PubMed] [Google Scholar]
28. Karimpour M., Feizi M.A.H., Mahdavi M., Krammer

- B., Verwanger T., Najafi F., Babaei E. Development of curcumin-loaded gemini surfactant nanoparticles: Synthesis, characterization and evaluation of anticancer activity against human breast cancer cell lines. *Phytomedicine*. 2019;57:183–190. doi: 10.1016/j.phymed.2018.11.017
29. Khan A.Q., Ahmed E.I., Elareer N., Fathima H., Prabhu K.S., Siveen K.S., Kulinski M., Azizi F., Dermime S., Ahmad A. Curcumin-mediated apoptotic cell death in papillary thyroid cancer and cancer stem-like cells through targeting of the JAK/STAT3 signaling pathway. *Int. J. Mol. Sci.* 2020;21:438. doi: 10.3390/ijms21020438. [DOI] [PMC free article] [PubMed] [Google Scholar]
 30. Kwon Y. Curcumin as a cancer chemotherapy sensitizing agent. *J. Korean Soc. Appl. Biol. Chem.* 2014;57:273–280. doi: 10.1007/s13765-014-4077-1. [DOI] [Google Scholar]
 31. Wilken R., Veena M.S., Wang M.B., Srivatsan E.S. Curcumin: A review of anti-cancer properties and therapeutic activity in head and neck squamous cell carcinoma. *Mol. Cancer*. 2011;10:12. doi: 10.1186/1476-4598-10-12. [DOI] [PMC free article] [PubMed] [Google Scholar]
 32. Ravindran J., Prasad S., Aggarwal B.B. Curcumin and cancer cells: How many ways can curry kill tumor cells selectively? *AAPS J.* 2009;11:495–510. doi: 10.1208/s12248-009-9128-x. [DOI] [PMC free article] [PubMed] [Google Scholar]
 33. Zhou H., Beevers C.S., Huang S. The targets of curcumin. *Curr. Drug Targets*. 2011;12:332–347. doi: 10.2174/138945011794815356. [DOI] [PMC free article] [PubMed] [Google Scholar]
 34. Lev-Ari S., Starr A., Vexler A., Karaush V., Loew V., Greif J., Fenig E., Aderka D., Ben-Yosef R. Inhibition of pancreatic and lung adenocarcinoma cell survival by curcumin is associated with increased apoptosis, down-regulation of COX-2 and EGFR and inhibition of Erk1/2 activity. *Anticancer Res.* 2006;26:4423–4430. [PubMed] [Google Scholar]
 35. Ghaderi S., Babaei E., Hussien B.M., Mahdavi M., Azeez H.J. Gemini curcumin suppresses proliferation of ovarian cancer OVCAR-3 cells via induction of apoptosis. *Anticancer Agents Med. Chem.* 2021;21:775–781. doi: 10.2174/1871520620666200807223340. [DOI] [PubMed] [Google Scholar]
 36. Sobhkhizi A., Babaei E., Azeez H.J., Katiraei F., Hussien B.M., Hoseinpour Feizi M.A. Dendrosomal nano-curcumin modulates P-glycoprotein activity and induces apoptosis in wild type and P53-mutant breast cancer cell lines. *Jentashapir J. Cell. Mol. Biol.* 2020;11:e109143. doi: 10.5812/jcmb.109143. [DOI] [Google Scholar]
 37. Ebrahimi M., Babaei E., Neri F., Feizi M.A.H. Anti-proliferative and apoptotic effect of gemini curcumin in p53-wild type and p53-mutant colorectal cancer cell lines. *Int. J. Pharm.* 2021;601:120592. doi: 10.1016/j.ijpharm.2021.120592. [DOI] [PubMed] [Google Scholar]
 38. Hajizadeh M., Hafez Ghoran S., Azeez H.J., Feizi M.A.H., Babaei E. Apoptotic effects of Gemini curcumin on MDA-MB-468 breast cancer cell line. *Anticancer Agents Med. Chem.* 2021;22:2181–2188. doi: 10.2174/1871520621666211015141928. [DOI] [PubMed] [Google Scholar]
 39. Jabbari N., Hafez Ghoran S., Semsari H., Hussien B., Babaei E. Gemini Curcumin suppresses gastric cancer AGS cells proliferation through modulation of lncRNA CCAT2 and c-Myc genes. *Turk. J. Pharm. Sci.* 2022;19:239–245. doi: 10.4274/tjps.galenos.2021.03502. [DOI] [PMC free article] [PubMed] [Google Scholar]
 40. Taj L., Norhaizan M.E. Curcumin combination chemotherapy: The implication and efficacy in cancer. *Molecules*. 2019;24:2527. doi: 10.3390/molecules24142527. [DOI] [PMC free article] [PubMed] [Google Scholar]
 41. IANS, Turmeric effective in treating various types of cancer, The Indian Express-2016
 42. The Indian Express online archive, Turmeric may help in treating blood cancer, say IIT Madras researchers Updated on: 14 Jul 2020.
 43. Kendall K. Morgan, Medically Reviewed by Laura J. Martin, Can turmeric fight cancer, 2024, WebMD, Cancer reference